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DRAFT FOR REVIEW

Developing a Framework for Applying Off-Model Emissions Reduction Strategies

Prepared by the Texas A&M Transportation Institute

Prepared for the Texas Department of Transportation

August 2013

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Developing a Framework for Applying Off-Model Emissions Reduction Strategies

Air Quality and Conformity Inter-Agency Contract

Subtask 2.9 – FY 2013

Prepared for

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By

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INTRODUCTION

This report summarizes work performed in Fiscal Year 2013 (FY2013) on Subtask 2.9 (Developing a Framework for Applying Off-model Emissions Reduction Strategies) under the Air Quality and Conformity Inter-Agency Contract. The intent of this task was originally to provide guidance and support to Metropolitan Planning Organizations (MPOs) who were looking to employ off-model strategies for conformity purposes. However, due to the fact that anticipated lowering of the National Ambient Air Quality Standards (NAAQS) did not take place, and due to several other factors, MPOs and TxDOT did not require this assistance in FY2013. The task was therefore refocused to provide tools that could be of future use to TxDOT and its partner agencies. This task follows up on previous TTI work (conducted from FY2009 to FY2012), which involved ad-hoc assistance to TxDOT and Texas MPOs in non-attainment areas in the evaluation of emissions control strategies as well as developing draft estimation tools for selected strategies.

A set of generally-applicable on-road mobile source emissions reduction strategies was identified previously. The research team also developed a framework by which transportation agencies can identify useful strategies and estimate potential emissions reductions that could be achieved through their implementation through "off-model" analyses. Off-model analyses are broadly defined by the Federal Highway Administration (FHWA) as the evaluation of possible emission reductions without the specific use of a Travel Demand Model[1]. Off-model analyses have been widely applied to transportation conformity analyses (with a view of potentially supporting the inclusion of control strategies in the state implementation plan (SIP) to obtain credits), for Congestion Mitigation and Air Quality (CMAQ) Improvement Program project justifications, and for sketch-planning applications.

This task expands on the previous TTI work by implementing them in a user-friendly spreadsheet-based emission estimation tool. A new off-model strategy was also identified and included in this tool. The new strategy is based on North Central Texas (NCT) Clean School Bus Program which includes upgrading school bus fleet.

IDENTIFICATION OF EMISSIONS REDUCTION STRATEGIES FOR INCLUSION IN THE STUDY

The factors that influence the selection of an emissions control strategy for evaluation or implementation include: 1) the transportation agency's level of interest in the strategy, or the overall feasibility of implementing the strategy in terms of political or other concerns; 2) whether

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[1] Edwards, A. 1999. Off-Model Air Quality Analysis: A Compendium of Practice. Federal Highway Administration, Southern Resource Center.

the impacts of the strategies can be scientifically quantified; and 3) whether the strategies can potentially achieve a reasonable magnitude of emissions reductions and be cost effective.

In previous studies, TTI classified emissions reduction strategies generally applicable to mobile source emissions as follows[2]:

- Transportation and Land Use Strategies
- Vehicle and Fuel Standards and Technologies
- Transportation Control Measures (including vehicle miles of travel (VMT) reduction and fuel use reduction strategies)
- Fleet Strategies for Emissions Reduction
- Incentive and Voluntary Programs.

While many of the strategies have similar impact in reduction of all pollutants – for example, those that directly relate to reduction in vehicle miles of travel (VMT) – others (such as vehicle retrofit technologies) may be applicable only to specific pollutants, or may reduce different pollutants at different levels. The following eight strategies have been frequently considered for use or analyzed in Texas and were selected for final inclusion in the framework developed in FY2012:

- Implementation of Anti-Idling Policy
- Idle Reduction for Long-Haul Trucks
- Vehicle Fleet Electrification
- Transit Facilities
- High Occupancy Vehicle (HOV) Facilities
- Mixed-Use Developments
- Retiming of Traffic Signals
- Bicycle Facilities

In FY13, the researchers found further information on NCT Clean School Bus program and a decision was made to add it to the framework. The selection was based on strategies that were previously identified as being of interest to TxDOT and Texas MPOs during work performed for the El Paso, Beaumont-port Arthur (BPA) and Houston-Galveston-Brazoria (HGB) regions, as well as work done by NCTCOG staff. Additionally, strategies identified by TTI staff as having the potential to reduce emissions and also have those reductions quantified in a consistent and scientific manner were included. Other strategies that were identified or considered for inclusion, and can potentially be used to expand the framework and spreadsheet calculator, are listed below:

1) Strategies for PM Reduction

[2] Texas Transportation Institute. *Compendium of Control Strategies for Mobile Source Greenhouse Gas Emissions* – Draft Report prepared for the Texas Department of Transportation, 2010.

   a. Diversion of heavy duty vehicles from local roads onto freeways
   b. Roadway sweeping
   c. Paving of unpaved roads
2) Vehicle Retrofits
   a. Diesel Particulate Filters
   b. Diesel Oxidation Catalysts
   c. Scrappage Programs for older heavy duty vehicles
3) Speed Limit Reductions/Environmental Speed Limits
4) Park and ride lots
5) Commuter programs, such as:
   a. Compressed work week
   b. Flexible work schedule
   c. Carpool or alternative transportation incentives
   d. teleworking
6) Fueling of Vehicles in the Evening
7) Ozone Action Day Education Programs
8) Restrictions in off-road vehicle equipment use hours
9) Smoking Vehicle Program

DESCRIPTION AND QUANTIFICATION APPROACH FOR THE SELECTED STRATEGIES

This section describes the strategies and the general approach to computation of emissions reductions associated with them. Appendix A contains further details and equations developed for the computation. Where applicable, the methodologies and quantification approaches are developed to be consistent with the equations in MOSERS.

Strategy 1: Implementation of Anti-Idling Policy

This strategy considers the implementation of an anti-idling policy targeting local heavy-duty fleets (i.e., short-haul truck fleets). The reduction of emissions is evaluated by considering the effect of placing restrictions on idling time. For example, the implementation of a "five minute" idle restriction, which would reduce the overall time these vehicles idle, and consequently, the associated emissions. This strategy can be applied at a regional level (e.g., a county) and requires identifying a target fleet (e.g., short-haul diesel trucks) and knowledge of compliance and existing idling levels. The levels of compliance, number of target vehicles, and average idling time per vehicle prior to implementation of an idling restriction vary significantly from one county to another; however, many counties in Texas such as Bastrop, Caldwell, Hays, Travis, and Williamson allow a maximum idling time of 5 minutes from April to October[3].

[3] Compendium of Idling Regulations, https://tp-exp.com/uploads/idling_chart_2009.pdf.

Strategy 2: Idle Reduction for Long-Haul Trucks

This strategy can reduce emissions by reducing the extended idling of long-haul trucks during mandatory rest periods. The estimation of this is based on usage of electrified parking spaces (i.e., truck stop electrification, TSE) or auxiliary power units (APUs) as an alternative to idling the truck engine. This strategy can be applied to all truck stops at a regional or county level. The target fleet is heavy-duty diesel long-haul trucks. TTI has performed previous research on utilization of truck spot parking spaces, including those with and without TSE. Average occupancy rates of parking spaces with and without TSE are 0.27 and 0.50 according to a TTI study [4], and these values are suggested to be used as defaults.

Strategy 3: Vehicle Fleet Electrification

This strategy considers the potential impact of increasing the market share of electrified vehicles (hybrids, plug-in hybrids or fully-electric vehicles) over and above the projected fleet penetration levels through implementation of a marketing/incentive program. This strategy can be applied at a regional level. The quantification of emissions reductions is attributed to reduced emissions rates of these vehicles in comparison with the fleet averages.

Strategy 4: Transit Facilities

This strategy considers the expansion of existing transit (specifically, bus) facilities or service, or introduction of new service. The emissions reductions are attributed to the VMT reduced by transit users who were originally automobile users. This strategy can be applied to selected projects or quantified at a regional level. This strategy will require knowledge of the new transit ridership, daily VMT of transit caused by new service, and the percentage of those new users that previously were automobile drivers. This percentage varies significantly from city to city; for example, it is as low as 60 percent in Washington D.C., but it can reach 100 percent in Denver[5].

Strategy 5: High Occupancy Vehicle (HOV) Facilities

This strategy considers HOV facilities – separate lanes on controlled access highways- that are created for vehicles containing a specified minimum number of passengers. In this case, emissions reductions computed are based on reduced VMT due to increased occupancy. This strategy can be applied to existing HOV facilities or planned facilities as contained in an approved transportation plan. As currently structured, this estimation method does not include HOT lanes on which single occupant vehicles are permitted for a toll during off-peak traffic periods.

Strategy 6: Mixed-Use Developments

Mixed land uses can reduce vehicle trips through “internal trip capture” by locating various land uses adjacent to each other. This measure can be applied to planned or existing mixed-use

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[4] Zietsman, J., M. Farzaneh, W. Schneider, J. Lee., and P. Bubbosh. http://tse.tamu.edu/pdfs/Truck_Stop_Electrification_as_a_Strategy.pdf.

[5] ICF Consulting and Center for Urban Transportation Research. *Analyzing the Effectiveness of Commuter Benefits Programs*. TCRP 107, prepared for the Transportation Research Board of the National Academies, 2005.

developments. The estimation method, trip generation rates and internal capture rates are based on Institute of Transportation Engineers (ITE) recommendations [6].

Strategy 7: Coordination and Retiming of Traffic Signals

This measure considers the potential improvement of signal timing at intersections that can reduce emissions by reducing vehicle delay. This strategy can be applied on a project basis, for example for an arterial or corridor, or for a region. The quantification methodologies are based on the Texas Guide to Accepted Mobile Source Emission Reduction Strategies[7]. This strategy requires knowledge of traffic conditions before and after signal retiming, such as VMT, total delay and stops, and cruise speed along the corridor.

Strategy 8: Bicycle Facilities

This measure considers the potential impact of a new bicycle facility that can attract more cyclists. Based on this increasing number of cyclists, the reduction of VMT and emissions are estimated. This strategy can be applied on a project level or for a region, and the estimation methodology for increased bicycle trips is from a National Cooperative Highway Research Program Report NCHRP 552 [8].

Strategy 9: Upgrading School Bus Fleet

This measure is adopted from the North Central Texas (NCT) Clean School Bus Program. As a part of this program, financial assistance was provided through a competitive call for projects for retrofitting, repowering and replacing older, high polluting school buses. Based on these upgrades, the reduction of emission rates and total emissions are estimated. This strategy can be applied on a single vehicle- or for a fleet. The estimation methodology and assumption were developed by NCTCOG.[9]

DATA REQUIREMENTS FOR EVALUATION OF STRATEGIES

The quantification of the emissions reduction strategies described in this report requires various input data and assumptions. The most critical input is the emissions rates, which depends on the pollutant of interest, the analysis year and the region/county. For example, if the strategies are being applied to evaluate NOx reductions in the HGB region for the year 2020, appropriate emissions factors will need to be identified from MOVES and applied to the computation methodologies. Depending on the strategy being evaluated, emissions factors for different vehicle types may be required. Table 1 summarizes the other inputs required for the evaluation of

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[6] *Trip Generation Handbook: An ITE Recommended Practice, 2nd ed*. Institute of Transportation Engineers, Washington, D. C., 2004.

[7] *The Texas Guide to Accepted Mobile Source Emissions Reduction Strategies,*Texas Department of Transportation/Texas Transportation Institute, 2007.

[8] Krizek, K. J., G. Barnes, G. Poindexter, P. Mogush, K. Thompson, D. Levinson, N. Tilahun, D. Loutzenheiser, D. Kidston, W. Hunter, D. Tharpe, Z. Gillenwater, and R. Killingsworth. *Guidelines for Analysis of Investments in Bicycle Facilities*. NCHRP 552, prepared for the Transportation Research Board of the National Academies, 2006.

[9] Review of Texas' Clean School Bus Program, Environmental Defense Fund, 2012.

each of the strategies. Potential data sources for these include local studies or surveys, planning documents, and data from local agencies such as the city, county, transit agency, etc.

Table 1. Summary of Required Inputs for Each Strategy

Strategy	Inputs Required for Quantification
Implementation of Anti-Idling Policy	• Number of target vehicles (vehicles per day); • Average idling time per vehicle prior to implementation of restriction (hours per vehicle); • Time vehicles are allowed to idle under new restriction (hours per vehicle); and • Compliance factor (percentage).
Idle Reduction for Long-Haul Trucks	• Number of available parking spaces with and without TSE; • Average daily utilization of parking spaces with and without TSE
Vehicle Fleet Electrification	• Number of electrified vehicles considered to replace existing passenger cars due to implementation of specific incentives/programs; • Average daily VMT per vehicle (mile); and • Emissions factor after replacement (gram/mile) – in the case of a mix of vehicles being considered (for example, hybrids and electric vehicles), a weighted average value may be used.
Transit Facilities	• New transit ridership (persons/day); • New transit VMT; and • Percentage of users of new/expanded transit services that previously were automobile drivers (percentage).
HOV Facilities	• Total number of vehicles using/expected to use HOV lanes (vehicles per day); • Average trip length on HOV facility (miles); • Existing average passenger car occupancy (persons/vehicle); and • HOV occupancy (persons/vehicle).
Mixed Use Developments	• Area of office land use (square feet); • Area of retail land use (square feet); • Dwelling units of residential land use; and • Average trip length.
Retiming of Traffic Signals	• Length of corridor or network (miles); • Total delay before and after retiming (hours); • Cruise speeds before and after retiming (mph); and • Volumes of peak and off-peak periods (vehicles/hour).
Bicycle Facilities	• Percentage of adults in population; • Average passenger car occupancy (adult persons per vehicle); • Bicycle rates; and • Populations for areas within 0.25, 0.25 to 0.50, and 0.50 to 1.00 mile from the bicycle facility.
Upgrading School Bus Fleet	• Average distance driven; • Model year of the vehicle being upgraded; and • Emissions rates or reductions after upgrade.

DEVELOPMENT OF SPREADSHEET-BASED ANALYSIS TOOL

The methodologies described in the previous section were compiled in the form of a generic, user-friendly analysis tool that could be used to evaluate individual strategies or to compare and contrast various strategies and the potential emissions reductions.

The analysis tool is developed in the form of a Microsoft® Excel workbook, with dropdown menus and input worksheet that is linked to appropriate calculations. Figure 1 shows the main page of the analysis tool, from which users may select a specific strategy that they wish to evaluate. The tool is currently set up to be generic, and allow for the computation of emissions reductions from three pollutants[10] based on emissions factors entered by the user.

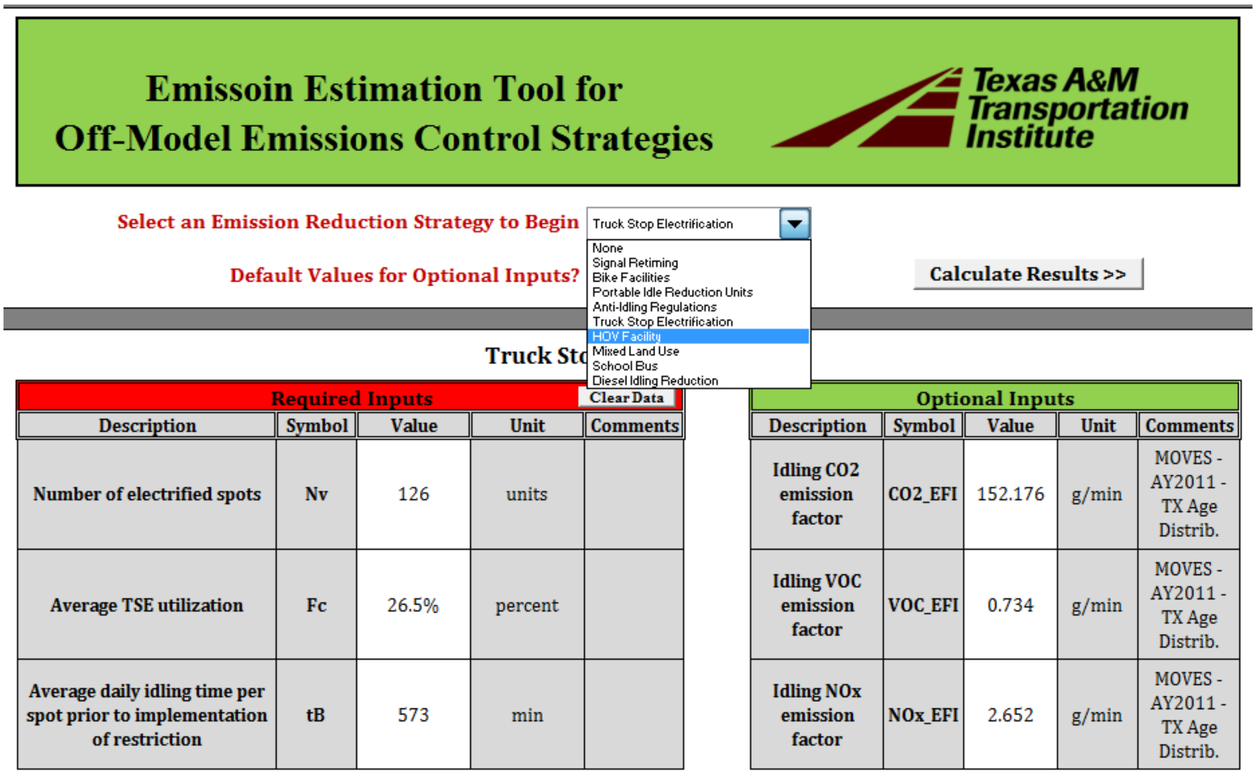

Figure 1. Main Page of Analysis Tool.

Users can select their desired strategy and whether they would like to use default values for optional input parameters. Each of the individual strategies has worksheets in which all the calculations are performed. Additional calculations for certain strategies, as well as look-up tables for emissions (which may be entered by the user, instead of single emissions rates values),

[10] Depending on data availability for each specific strategy.

are included as hidden cells and hidden worksheets. Advanced users may unhide these and modify if they so choose.

CONCLUSIONS AND NEXT STEPS

The work summarized in this task report provides a framework that TxDOT and its partner agencies, such as MPOs, can use to evaluate emissions reduction strategies in Texas. In terms of future/follow-up activities, TTI can work with TxDOT to use the tools developed to conduct specific analyses for Texas non-attainment or near-nonattainment areas interested in evaluation of these strategies. TTI will be able to work with TxDOT and the relevant MPOs to identify and collect data, generate MOVES emissions rates, make recommendations on assumptions, and perform analyses. Based on input from TxDOT and other agencies, additional emissions reduction strategies can also be included in the framework, and further refinements can be made to the computations for the existing strategies and the spreadsheet-based tool.

APPENDIX A – QUANTIFICATION EQUATIONS FOR EMISSIONS REDUCTION STRATEGIES

Implementation of Anti-Idling Policy - Quantification

Equations (*1*) through (*3*) show the general quantification of the impact of this strategy.

Daily Emission Reduction (grams/day) = $A * B$ (*1*)

$$A = N_V * F_C \quad (2)$$

The number of vehicles with restricted idling time multiplied by the percentage of vehicles in compliance with the strategy

$$B = EF_I * (t_B - t_A) \quad (3)$$

The reduction in idling exhaust emissions from reduced time spent in idling

Where,

EF_I = Idling emissions factor for the target fleet (grams/hour);

F_C = Compliance factor, i.e., percentage of vehicles in compliance with the strategy (percentage);

N_V = Number of vehicles in the target fleet found to idle per day (vehicles per day);

t_A = Time vehicles are allowed to idle under new restriction (hours per vehicle); and

t_B = Average idling time per vehicle prior to implementation of restriction (hours per vehicle).

Idle Reduction for Long-Haul Trucks – Quantification

Equations (*4*) through (*6*) shows the general quantification of the impact of this strategy.

Daily Emission Reduction (gram/day) = $A + B$ (*4*)

$$A = 24 * N_1 * AVR_1 * P_{APU} * (EF_I - EF_{APU}) \quad (5)$$

Emissions reduced by using APU

$$B = 24 * N_2 * AVR_2 * EF_I \quad (6)$$

Emissions reduced by using TSE

Where,

AVR_1	=	Average daily utilization of parking spaces without TSE (percentage);
AVR_2	=	Average daily utilization of parking spaces with TSE (percentage);
EF_{APU}	=	Emissions factor of using APU (gram/hour);
EF_I	=	Idling emissions factor for the target fleet (gram/hour);
N_1	=	Number of parking spaces without TSE;
N_2	=	Number of parking spaces with TSE; and
P_{APU}	=	Percentage of vehicles in non-TSE spaces using APU (percentage).

Vehicle Fleet Electrification - Quantification

Equations (*7*) through (*9*) show the general quantification of the impact of this strategy.

Daily Emission Reduction (grams/day) = $A * B$ (*7*)

$$A = N_E * VMT_{AVE} \quad (8)$$

Total VMT

$$B = EF_B - EF_A \qquad (9)$$

The change in pre-replacement and post-replacement emission factors

Where,

EF_A	=	Emissions factor after replacement (i.e., for a representative "electrified" vehicle – this value would be zero for purely electric vehicles, but will have a value for hybrids or PHEVs; gram/mile);
EF_B	=	Emissions factor before replacement – i.e., average emissions factor for a Light-duty vehicle in the fleet (gram/mile);
N_E	=	Number of electrified vehicles considered to replace existing passenger cars due to incentives/programs put in place (i.e., over and above levels that are ordinarily projected and included in the MOVES model or other emissions rates); and
VMT_{AVE}	=	Average daily VMT per vehicle (mile).

Transit Facilities - Quantification

Equations (10) through (12) show the general quantification of the impact of this strategy.

Daily Emission Reduction (gram/day) = $A - B$ (*10*)

$$A = VMT_R * EF_B \qquad (11)$$

Reduction in running emissions from passenger car VMT reductions

$$B = VMT_T * EF_T \qquad (12)$$

Increase in emissions from additional transit running emissions

Where, $VMT_R = VT_R * TL_W$ and $VT_R = N_{TR} * F_{T,SOV}$

Where,

EF_B	=	Emissions factor for passenger cars on affected roadway or region before implementation of transit service (grams/mile);
EF_T	=	Emissions factor for transit buses (grams/mile);
$F_{T,SOV}$	=	Percentage of users of new/expanded transit services that previously were automobile drivers (percentage);
N_{TR}	=	New transit ridership (persons/day);
VMT_R	=	Reduction in daily automobile VMT (miles);
VMT_T	=	New transit VMT (miles);
VT_R	=	Reduction in number of daily automobile vehicle trips (trips/day); and
TL_W	=	Average auto trip length (miles).

High Occupancy Vehicle (HOV) Facilities – Quantification

Equation (*13*) through (*15*) shows the general quantification of the impact of this strategy.

Daily Emission Reduction (grams/day) = $A - B$ (*13*)

$$A = EF_B * TL_W * N_P * AVO_A / AVO_B \quad (14)$$

Running emissions before the HOV lanes are created

$$B = EF_B * TL_W * N_P \quad (15)$$

Running emissions after the HOV lanes are created

Where,

AVO_A	=	Average HOV occupancy (persons/vehicle);

AVO_B = Existing average passenger car occupancy (persons/vehicle);

EF_B = Emissions factor for passenger cars (grams/mile);

N_P = Total number of vehicles using/expected to use HOV lanes (vehicles per day); and

TL_W = Average auto trip length (miles).

Mixed-Use Developments - Quantification

- Step 1- Document Characteristics of Multi-Use Development (three use types).
- Step 2 - Compute Baseline Trip Generation for Individual Land Uses (based on size/number of units and standard trip generation rates).
- Step 3- Estimate Anticipated Internal Capture Rate between Each Pair of Land Uses.
- Step 3a - Estimate "Unconstrained Demand" Volume by Direction.
- Step 3b - Estimate "Balanced Demand" Volume by Direction.
- Step 4 - Estimate the Internal and External Trips for Each Land Use.
- Step 5 - Estimate the reduction of VMT and translate to emissions (i.e., emissions reduced = daily trips reduced x average trip length x emissions factor).

Required inputs for this strategy include:

- Area of office land use (square feet);
- Area of retail land use (square feet);
- Dwelling units of residential land use;
- Average trip length; and
- Emissions factor,

Retiming of Traffic Signals- Quantification

Equations (*16*) through (*20*) show the general quantification of the impact of this strategy.

Daily Emission Reduction (grams/day) = $A+B+C+D$ (*16*)

$$A = (D_B - D_A) * EF_I * V_{D,P} \qquad (17)$$

Change in idling emissions from reduced vehicle delay times volume during the peak period

$$B = (D_B - D_A) * EF_I * V_{D,OP} \qquad (18)$$

Change in idling emissions from reduced vehicle delay times volume during the off-peak period

$$C = (EF_{B,P} - EF_{A,P}) * L * V_{D,P} \qquad (19)$$

Change in running emissions times volume during the peak period

$$D = (EF_{B,P} - EF_{A,P}) * L * V_{D,OP} \qquad (20)$$

Change in running emissions times volume during the off-peak period

Where,

D_A = Average vehicle delay at intersections (hours) after implementation;

D_B = Average vehicle delay at intersections (hours) before implementation;

$EF_{A,OP}$ = Speed based running exhaust emission factor during off-peak period (grams/mile) after implementation;

$EF_{A,P}$ = Speed based running exhaust emission factor during peak period (grams/mile) after implementation;

$EF_{B,OP}$ = Speed based running exhaust emission factor during off-peak period (grams/mile) before implementation;

$EF_{B,P}$ = Speed based running exhaust emission factor during peak period (grams/mile) before implementation;

EF_I = Idling emission factors (grams/hour);

L = length of corridor affected by signalization project (miles);

$V_{D,OP}$ = Average daily volume for the corridor during off-peak period; and

$V_{D,P}$ = Average daily volume for the corridor during peak period.

Bicycle Facilities- Quantification

Equations (*21*) through *(25*) show the general quantification of the impact of this strategy.

$$\text{Daily Emission Reduction (grams/day)} = \frac{A+B+C}{AVO} * D \qquad (21)$$

$$A = P_1 * AR * BR * IR_1 \qquad (22)$$

Increased bicycle trips within 0.25 mile from the bicycle facility

$$B = P_2 * AR * BR * IR_2 \qquad (23)$$

Increased bicycle trips within 0.25 to 0.50 mile from the bicycle facility

$$C = P_3 * AR * BR * IR_3 \qquad (24)$$

Increased bicycle trips within 0.50 to 1.00 mile from the bicycle facility

$$D = EF_B * TW_L \qquad (25)$$

Emission factor times the average trip length

Where,

AR = Percentage of adults in population;

AVO = Average passenger car occupancy (adult persons per vehicle);

BR = Bicycling rates; (0.02 for low estimation, 0.028 for moderate estimation, and 0.066 for high estimation);

EF_B = Emissions factor (grams/mile);

IR_1 = Trip increase rate within 0.25 mile from the bicycle facility (recommended default value of 1.93 from NCHRP Report);

IR_2 = Trip increase rate within 0.25 to 0.50 mile from the bicycle facility (recommended default value of 1.11 from NCHRP report);

IR_3 = Trip increase rate within 0.50 to 1.00 mile from the bicycle facility (recommended default value of 0.39 from NCHRP report);

P_1 = Population for area within 0.25 mile from the bicycle facility;

P_2 = Population for area within 0.25 to 0.50 mile from the bicycle facility;

P_3 = Population for area within 0.50 to 1.00 mile from the bicycle facility; and

TL_W = Average auto trip length (mile).

School Bus Upgrade- Quantification

Steps 1 through 4 below show the general quantification of the impact of this strategy.

Step 1. Determining the On-Road TxLED Correction Factor

If the fuel type is diesel, a correction factor of 0.943 should be applied; otherwise a correction factor of 1 is used.

2. Determine Baseline NOx Emission Factor (g/mile)

Baseline NOx emission factor =
Baseline engine NOx emission standard × TxLED correction factor × Conversion factor

3. Determine Reduced NOx Emission Factor (g/mile)

Option A. Reduced-emission engine certified to a specific emissions standard (g/bhp-hr)

Reduced NOx emission factor =
Reduced engine NOx emissions standard × TxLED correction factor × Conversion factor

Option B. Reduced-emission technology certified/verified to achieve a percentage reduction from the baseline

Reduced NOx emission factor =
Baseline NOx emission factor × Certified/verified percentage reduction from baseline

4. Calculate the NOx Emission Reduction Using Annual Mileage

Estimated activity life NOX emission reduction =

(Baseline NOX emission factor-Reduced NOX emission factor) × Annual miles of operation × Percent within affected counties × Activity Life

The Baseline NOX Emission Standard and Conversion Factor are determined based on the Model Year using the values froom Table 2 and 3.

Table 2. On-Road Heavy-Duty CI Engines NOx Emission Standards by Model Year.

Year of Manufacture	Diesel Engines Emission Standard	
	NO_X Only (g/bhp-hr)	NO_X+NMHC (g/bhp-hr)
1989 and earlier	10.7	
1990	6	
1991-1997	5	
1998-2003	4	
2004-2006*	2.375 - 4.0	
2007-2009*^	0.2 - 2.375	2.5
2010+ *	0.2	---

* Due to engine phase-in schedules, any application request for a 2003 or newer engine must include a family engine code to determine emissions levels.

^ If the family code is not known for a 2007 or newer engine, use the 2006 standard, 2.375 g/bhp-hr.

Table 3. On-Road Heavy-Duty Diesel School Bus Conversion Factors (HDDBS).

Model Year	Conversion Factor (bhp-hr/mi)	Energy Consumption Factor (ECF) (bhp-hr/gal)
0	0.00	0
1900	1.60	14.6
1980	1.60	14.6
1981	1.61	14.8
1982	1.62	15.0
1983	1.62	15.3
1984	1.62	15.5
1985	1.62	15.7
1986	1.62	15.9
1987	1.62	16.1
1988	2.67	16.3
1989	2.69	16.5
1990	2.70	16.8
1991	2.71	17.0
1992	2.77	17.3
1993	2.82	17.5
1994	2.88	17.8
1995	2.93	18.0
1996	2.99	18.3
1997	2.99	18.6
1998	2.99	18.8
1999	2.99	19.1
2000	2.99	19.4
2001	2.99	19.7
2002	2.99	19.9
2003	2.99	20.2
2004	2.99	20.5
2005	2.99	20.8
2006	2.99	21.2
2007	2.99	21.5
2008	2.99	--
2009	2.99	--
2010	2.99	--
2011	2.99	--